STATUS OF MINERAL RESOURCE INFORMATION

FOR THE LAGUNA INDIAN RESERVATION, NEW MEXICO

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SUMMARY AND CONCLUSIONS

Development of known mineral resources on the Laguna Reservation probably will be limited to expanded production of uranium and, to a lesser extent, rock products. Low-grade uranium occurrences are known and should be studied to determine their commercial potential by in-situ or heap-leaching techniques. Gypsum has potential for development if a wallboard or cement plant were to be established on or near Indian land. Coal resources are limited on the reservation, but the potential for development cannot be assessed without a detailed field investigation to determine location, quantity and quality of the coal. Clay deposits may have some development potential if large resources can be delineated.

INTRODUCTION

This report was prepared for the U. S. Bureau of Indian Affairs by the U. S. Geological Survey and the U. S. Bureau of Mines under an agreement to compile and summarize available information on the geology, mineral resources, and potential for economic development of certain Indian lands. Source material included published and unpublished reports, and personal communication. There was no field work.

The Laguna Indian Reservation (fig. 1) is in parts of Valencia, Bernalillo, and Sandoval Counties in west-central New Mexico about 40 miles (64.4 km) west of Albuquerque. The reservation, in four parts, totals 454,453.78 acres (183,599.3 ha). All land within the reservation is tribally owned. The tribe owns mineral rights on most of its lands, except on the Antonio Sedillo Grant in the southeastern part near the Valencia-Bernalillo County line and alternate sections in T. 6 N., R. 7 W. in the southern part where private interests hold the mineral rights (table 1). Mineral rights on the Sedillo Grant will become part of the Indian estate on August 13, 1988.

The reservation, situated along the southern border of the San Juan Basin, is a scenic region of mesas rising 100 to 300 feet (30.5 to 91.5 m) above surrounding broad flat valleys. Many of the mesas and hills have

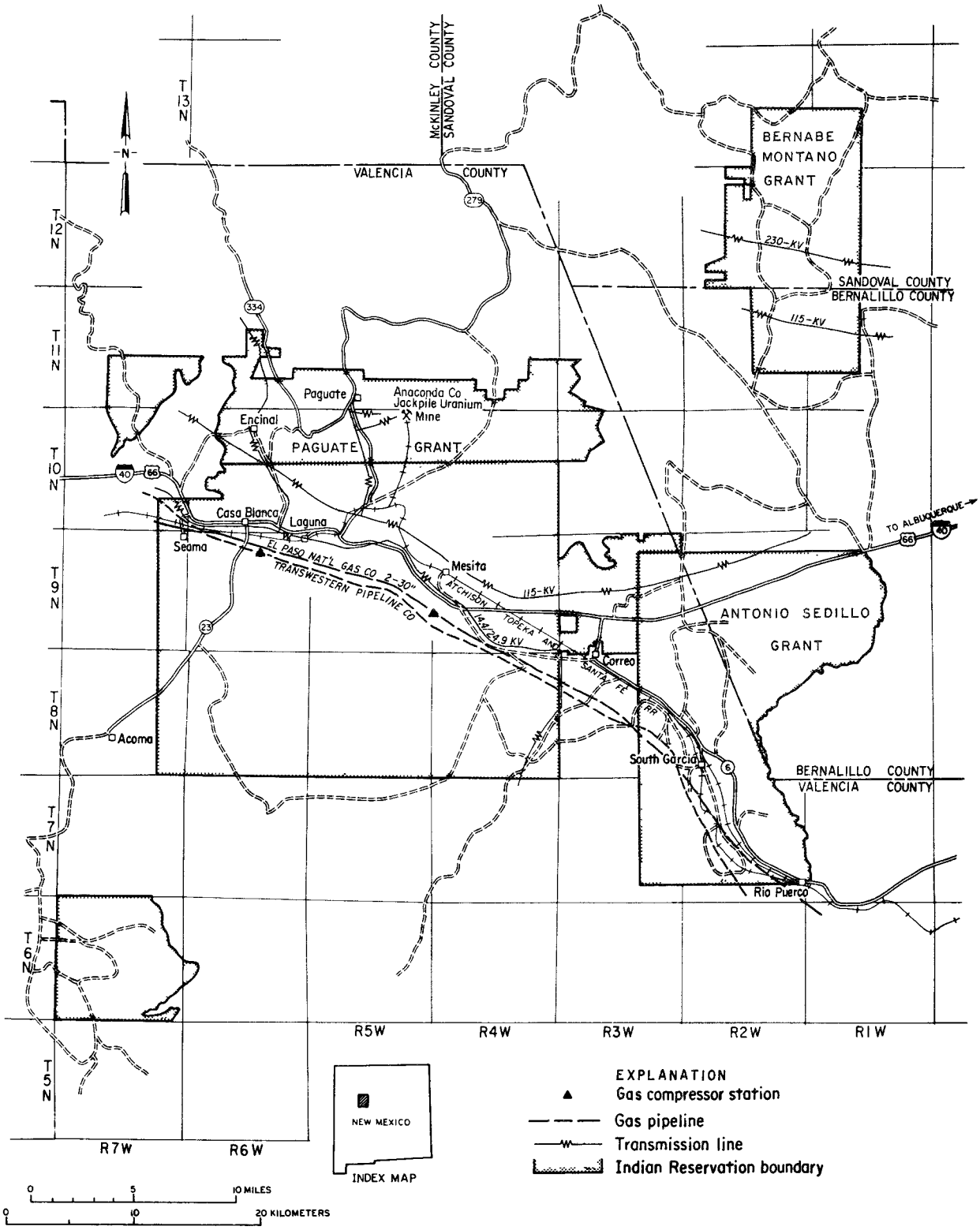

Figure 1.--Index map showing infrastructure of the Laguna Indian Reservation, New Mexico.

Table 1.--Areas on the Laguna reservation where mineral rights are outstanding

Owner	General area	Location: Section	Township	Range	Minerals owned
Wilson Trust Indenture [1/]	Antonio Sedillo Grant		[2/]		All.
New Mexico and Arizona Land Co. and Santa Fe Railroad.	Southern area	SW¼ 19	6 N	7 W	Oil and gas.
		NE¼ 19	6 N	7 W	
Do	do	Odd sections	6 N	6 W	Do.
U. S. Government	East central area	NE¼NE¼ 6	8 N	3 W	All.
		NE¼NW¼ 6	8 N	3 W	
Unknown	do	30	9 N	3 W	Do.
Santa Fe Railroad	do	S½ 31	9 N	3 W	Do.
Unknown	do	NE¼SE¼ 31	9 N	3 W	Do.
		SE¼SE¼ 31	9 N	3 W	
		SW¼SE¼ 31	9 N	3 W	
U. S. Government	Central area	3-10	9 N	5 W	Gold, silver, mercury.
		15-18	9 N	5 W	
Do	do	1	9 N	6 W	Do.
		12	9 N	6 W	
		13	9 N	6 W	
Unknown	Bernabe Montana Grant	N½ 32	12 N	2 W	All.
Do	do	S½ [3/] 4	12 N	2 W	Do.
Do	do	E½ [3/] 9	12 N	2 W	
U. S. Government	Northern area	27-34	10 N	5 W	Gold, silver, mercury.
Do	do	25	10 N	6 W	Do.
		36	10 N	6 W	

1/ - Mineral rights will become part of the Indian Estate on August 13, 1988.
2/ -- Includes all of the townships in the Grant.
3/ - As stated in the Bureau of Indian Affairs records.

a scattering of juniper and pinyon trees, and the highest parts, on the flanks of Mount Taylor, have a few scattered ponderosa pines. The area is drained by the Rio San Jose and its tributaries. Streams are all ephemeral except for the Rio San Jose which has a very small perennial flow. Interstate Highway 40 (U. S. 66) and the Atchison, Topeka, and Santa Fe Railroad cross the reservation. State and Bureau of Indian Affairs roads provide access to the north and south.

Principal towns in the region are: Albuquerque (population 243,751), Grants (population 8,768), Laguna (population 1,449), and Paguate (population 1,383).

PREVIOUS WORK

Early reports and maps of parts of the Laguna reservation include those by Bryan and McCann, (1937) Wright, (1946) and Kelley and Wood, (1946). Moench and Schlee (1964) made detailed maps of much of the reservation and prepared a comprehensive report of the area (fig. 2). Other parts of the reservation are covered by photogeologic maps (Hackman, 1967, Hemphill, 1967, and Knox, 1967). The Geological Survey recently published a detailed geologic map of the Acoma Pueblo quadrangle (Maxwell, 1976).

MAP SOURCES

The reservation is covered by U. S. Geological Survey topographic quadrangles. Most of the area has been mapped on the 7½-minute or 1:24,000 scale, but in one area only the 15-minute or 1:62,500 map is available. The following topographic maps, that cover the reservation area, may be purchased from U. S. Geological Survey, Branch of Distribution, Central Region, Box 25286, Denver Federal Center, Denver, Colo., 80225:

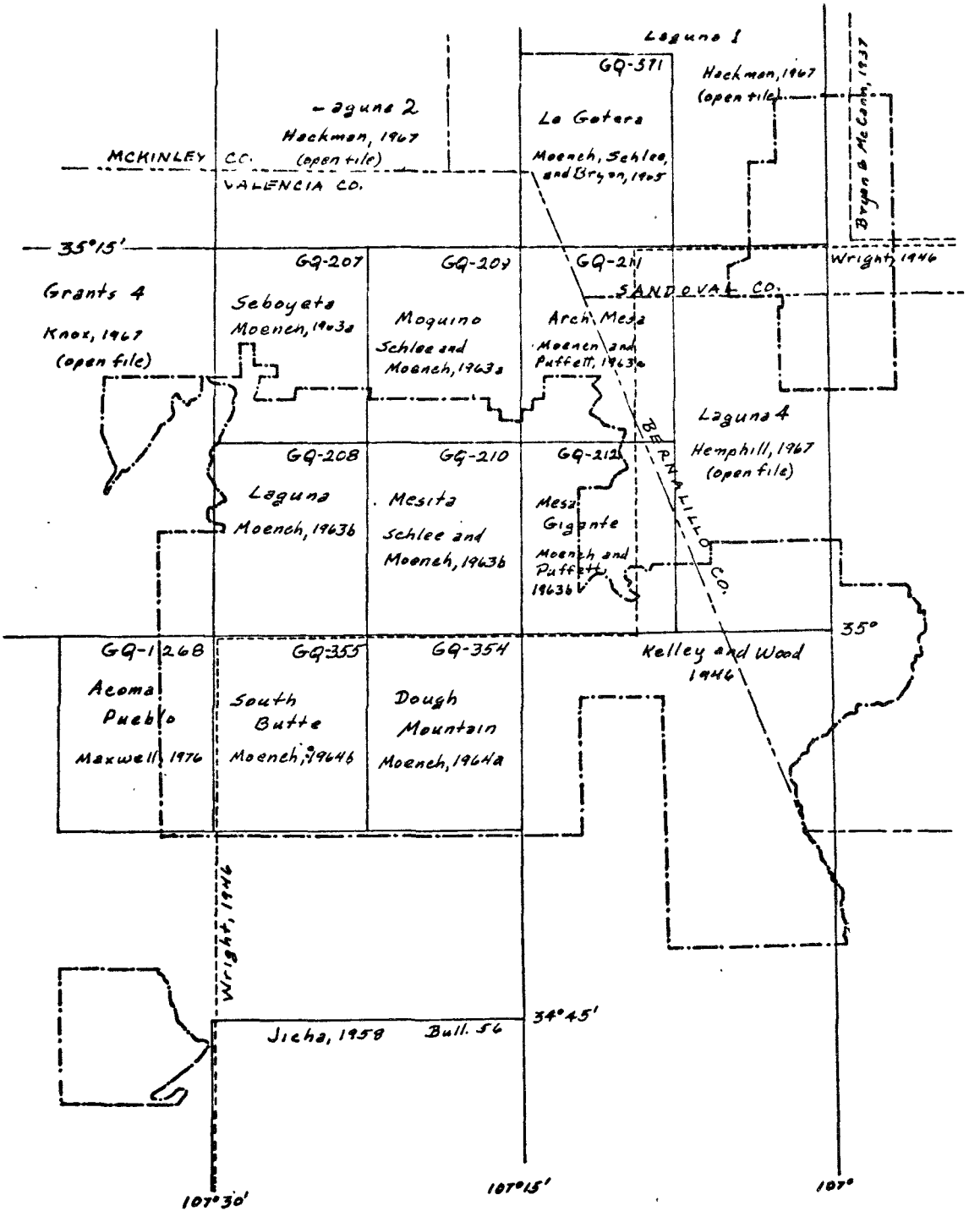

Figure 2.--Index of geologic mapping on and near Laguna Indian Reservation.

7½-Minute Quadrangles

Acoma Pueblo	East Mesa	Mount Taylor
Arch Mesa	Herrera	Perco Cam
Benavides	Laguna	Seboyeta
Broom Mountain	Marmon Ranch	Sky Village
Canoncito School	Mesa Gigante	South Butte
Cerro Verde	Mesita	South Garcia
Cubero	Moquino	South Garcia SE
Dough Mountain		

15-Minute Quadrangle

South Garcia

Another source of map coverage of the reservation is the U. S. Bureau of Land Management which has published both land status title plats and land status quadrangles. Both series of maps can be ordered from the Bureau of Land Management, Records Section, P. O. Box 1449, Santa Fe, N. Mex. An historical index can be obtained to accompany the master title plats. The quadrangles, master title plats and historical indexes should be ordered by township and range.

The New Mexico State Highway Department has county road maps available. Requests should be addressed to the New Mexico State Highway Department, Duplicating Services, P. O. Box 1149, Santa Fe, N. Mex. 87503. The New Mexico State Geological Survey in Socorro also is a good source of map information.

Areal photographs of the reservation may be purchased from both the U. S. Geological Survey and the U. S. Department of Agriculture. The agencies within the Department of Agriculture from which photos may be obtained are the U. S. Forest Service and the U. S. Soil Conservation Service. Satellite imagery can be obtained from the U. S. Geological Survey, EROS Data Center, Sioux Falls, S. Dak.

GEOLOGY

General

The rocks in the region are mostly sandstone and shale with lesser amounts of limestone, gypsum, and coal, capped here and there by basaltic lava flows. The sedimentary rocks range in age from about 300 my. (million years) to 1 my., and are covered over much of the area by surficial material that ranges in age from about 1 my. to today's sand and silt. The lava flows are all comparatively recent; the oldest are less than 3 my. Samples of lava flows from Mesa Chivato northwest of the reservation have been dated as 2.6 my. (Weber, 1971); the flows in the valley near Laguna are associated with Indian artifacts that indicate an age of less than 1,500 years.

The sedimentary rocks generally dip gently toward the northwest except they dip steeply east in some areas along a conspicuous broad fault zone in the eastern part of the reservation. This fault zone is the boundary between the Rio Grande Trench and the Colorado Plateau to the west.

Rock Units

The distribution of the rock units on the Laguna Reservation and surrounding areas is shown on the generalized geologic map (fig. 3). Table 2 summarizes the stratigraphic sequence and thickness of the rock units. Figure 4 diagrammatically represents the complex intertonguing of the Cretaceous rocks in the region.

Permian Rocks

Permian rocks crop out only in the southeasternmost part of the reservation, west of the Rio Puerco fault zone (fig. 3).

Abo Formation.--The Abo Formation consists of about 800 feet (270 m) of continental deposits, red-brown shale, siltstone, and sandstone, with a few thin limestone beds in the lower part.

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EXPLANATION

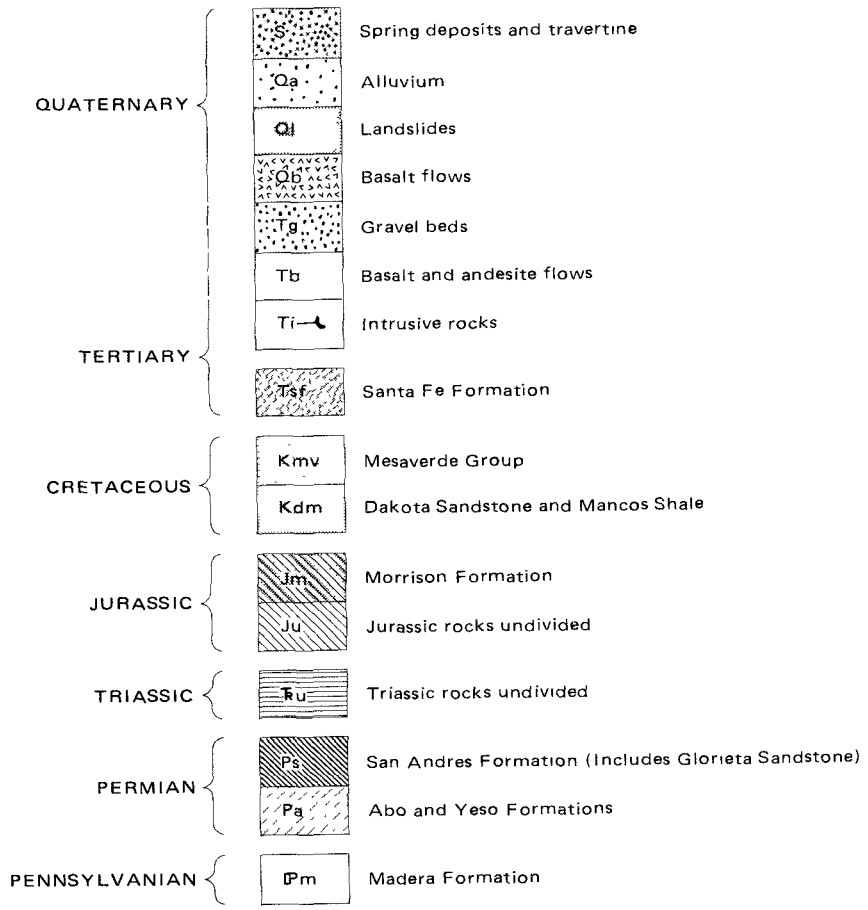

TABLE 2. STRATIGRAPHIC SEQUENCE OF SEDIMENTARY ROCK UNITS ON THE LAGUNA INDIAN RESERVATION

Symbols on Figure 3	Symbols on Figure 4	System or Period	Unit	Approximate thickness feet	Approximate thickness metres
		TERTIARY			
Tsf			Santa Fe Formation	6,000	2,000
		CRETACEOUS			
	Kmv		Mesaverde Group		
	Kpl		Point Lookout Sandstone	120	40
			Crevasse Canyon Formation		
	Keg		Gibson Coal Member	300	100
	Kcd		Dalton Sandstone Member	120	40
	Km		Mancos Shale		
	Kmm		Mulatto Tongue	250-320	80-100
Kmv			Crevasse Canyon Formation		
	Kcs		Stray Sandstone	20- 40	7-13
	Kcdi		Dilco Coal Member	160-180	55-60
	Kg		Gallup Sandstone	50-80	17-27
	Km		Mancos(?) Shale	100-120	35-40
	Kg		Gallup Sandstone	20-40	7-13
	Km		Mancos(?) Shale	25-60	8-20
	Kg		Gallup Sandstone	20-30	6-10
	Km		Mancos Shale (main body)	300-350	100-117
	Kd		Dakota Sandstone		
	Kdt		Twowells Sandstone Tongue	0-80	0-27
Kdm	Kmw		Mancos Shale, Whitewater Arroyo Tongue	70-140	23-47
	Kdp		Dakota Sandstone, Paguate Tongue	0-50	0-17
	Kmc		Mancos Shale, Clay Mesa Tongue	40-60	13-20
	Kdc		Dakota Sandstone, Cubero Tongue	25-60	8-20
	Kdo		Oak Canyon Member	60-90	20-30
	Kds		Basal sandstone units	0-60	0-20
		JURASSIC			
Jm	Jm		Morrison Formation	0-300	0-100
	Jz		Zuni Sandstone	10-300	3-100
	Jb		Bluff Sandstone	150-220	50-70
Ju			Jurassic undivided		
	Js		Summerville Formation	60-150	20-50
	Jtg		Gypsum beds	0-100	0-30
	Jt		Todilto Limestone	0-10	0-3
	Je		Entrada Sandstone	0-300	0-100
Tru	Tru	TRIASSIC			
			Triassic rocks undivided		
			Wingate Sandstone, Rock Point Member[1/]		
			Chinle Shale	300	100
				1,000	340
		PERMIAN			
Pa			San Andres Limestone	400-470	135-160
			Glorieta Sandstone	200	65
Pa			Yeso	820-1,020	270-340
			Abo Formation	780-880	260-290
		PENNSYLVANIAN			
			Madera Limestone[1/]	1,600-2,000	530-650

1/ Not present on reservation but is in immediately adjacent areas.

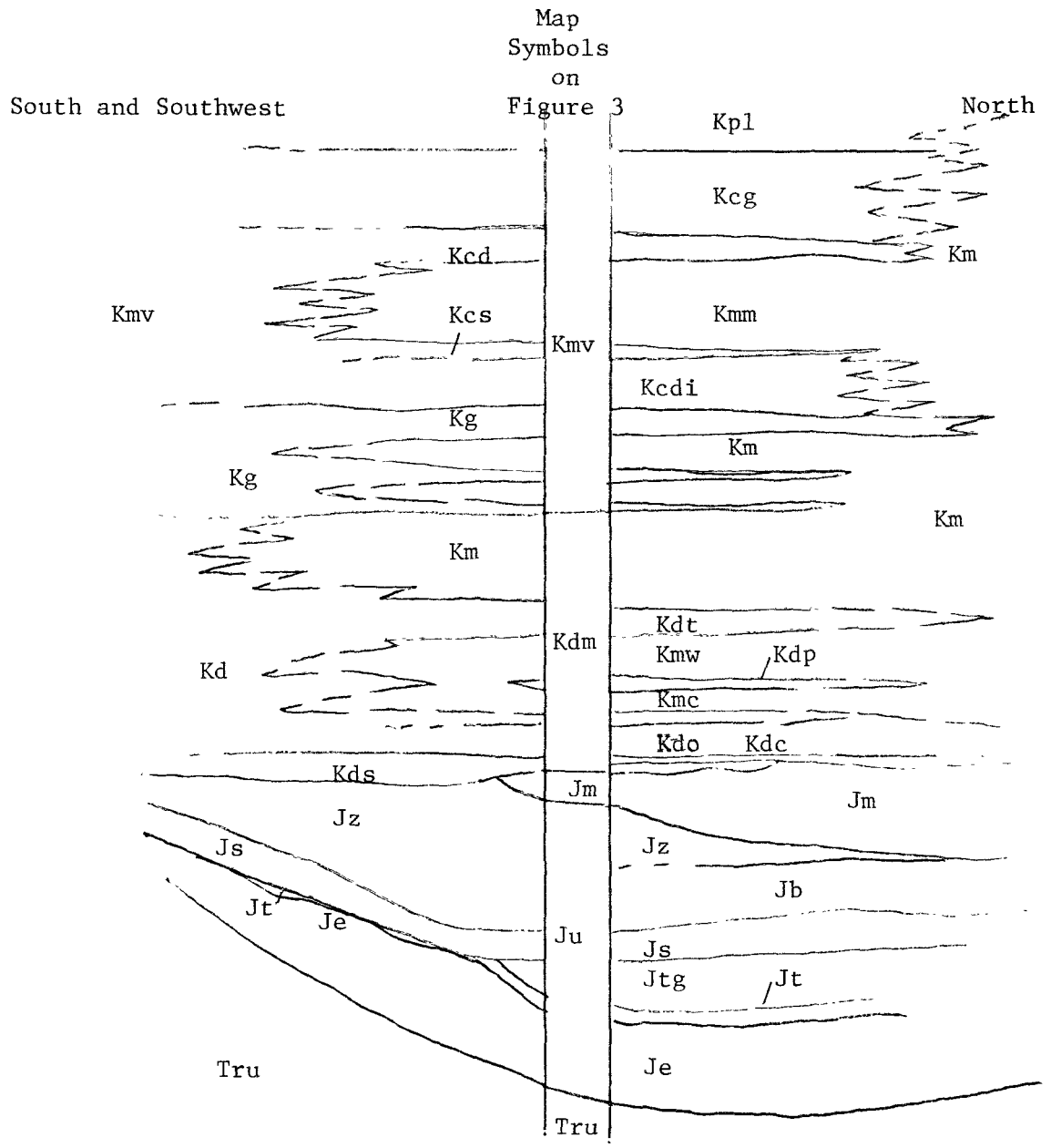

Figure 4.--Diagrammatic representation of stratigraphic relationships between Cretaceous and Jurassic rocks in and near the Laguna Indian Reservation.

Yeso Formation.--The Yeso Formation ranges from 800 to 1,100 feet (270-370 m) thick. It is composed of light brown and tan sandstone at the base, light tan and brown shale, siltstone, and sandstone with thin limestone and gypsum layers in the middle part, and similar rocks but with as much as 50 percent gypsum in the upper part.

Glorieta Sandstone.--The Glorieta Sandstone consists of an upper and lower buff-white massive crossbedded sandstone separated by a thin gypsum and shale unit.

San Andres Limestone.--The unit correlated with the San Andres Limestone consists of 300-350 feet (100-115 m) of massive sandstone, thick-bedded gray limestone, friable gypsiferous sandstone, and gypsum overlain by 100-200 feet (30-40 m) of medium to thin bedded gray limestone and shale.

Triassic rocks

Chinle Formation.--The Chinle Formation, about 1,000 feet (340 m) thick, is composed of variegated red, purple, and gray shale with lenses of mudstone, sandstone, and conglomerate. It is soft and easily eroded; outcrops form a characteristic badlands topography. The resistant sandstone and conglomerate lenses and beds form irregular mesas or hogbacks. The broad flat Arroyo Colorado valley and part of the San Jose valley is formed in the unresisting Chinle shale.

Wingate Sandstone.--The Rock Point Member of the Wingate Sandstone is exposed on the mesa slope east of the southwestern segment of the reservation. It is composed of about 250 feet (80 m) of light reddish-brown shaley siltstone and silty sandstone and white fine-grained sandstone.

Jurassic Rocks

Entrada Sandstone.--The Entrada Sandstone is composed of three units: a lower light orangish red sandstone member, variable in thickness and sporadic in occurrence; a medial silty member, dark red-brown, which is the base of the Entrada in most areas; and an upper eolian crossbedded sandstone, red-brown in the northern part of the area changing to light greenish white toward the southwest. The upper member forms the bold rounded cliffs along the base of Mesa Gigante and the tablelands south of Laguna.

Todilto Limestone.--The Todilto Limestone is a few metres thick in the central part of the reservation and pinches out southwest of the main reservation. It is composed of dark gray thin bedded to laminated fetid, petroliferous, silty limestone. It is the host rock for several uranium occurrences in the area, including the Sandy and Crackpot mines. An overlying but less extensive unit composed of 80 to 100 feet of gypsum and anhydrite is part of the Todilto. It is exposed north of Interstate 40 from near Mesita around the south end of Mesa Gigante, and in the fault zone in the southeastern part of the reservation. This unit is composed of nearly pure gypsum in surface outcrops, with very little limestone, silt, clay, or other impurities. In the subsurface it is nearly pure anhydrite, as indicated by drill hole 111 at the Jackpile mine (Moench and Schlee, 1967, p. 10).

Summerville Formation.--The Summerville Formation is composed of siltstone and very fine grained sandstone, red-brown, pink, and tan in the northern exposures, changing to light tan and white toward the southwest.

Bluff and Zuni Sandstones.--The Bluff and Zuni Sandstones are generally mapped together as one unit in the region. The Bluff is a fluviatile sandstone, reddish brown in the central and eastern part of the reservation, grading to light brown and tan to the west

and south. It is thickest in the north, thinning and merging with the Zuni to the south. The Zuni is a light-brown to tan eolian sandstone, thin but variable in thickness in the northern part and thickening to 300 feet or more to the south. The Bluff forms a conspicuous vertical cliff in most exposures, and the Zuni forms smoothly rounded steep slopes above the cliff in the central part of the reservation. To the southwest the two units merge and form spectacular vertical cliffs several hundred feet high.

Morrison Formation.--The Morrison Formation is the most important unit in the region, the host rock for all of the important uranium deposits, and is shown as a separate unit on the geologic map. The Morrison is truncated along an east-west line across the southern part of the reservation by the erosional unconformity at the base of the overlying Dakota Sandstone. The Dakota Sandstone also truncates the Jurassic and some of the Triassic rocks progressively southward (fig. 4).

The Morrison Formation has been divided into four members in the Laguna district (Moench and Schlee, 1967). At the bottom is the Recapture Member, overlain by the Westwater Canyon Member, the Brushy Basin Member, and at the top the Jackpile Sandstone. The Recapture in this area is a grayish-red and brownish-red sandstone with some interstratified mudstone at the top. It ranges from 10 to more than 50 feet thick, is locally absent, and is classified in part as a fossil soil zone in the western part of the reservation (Maxwell, 1976). The next overlying unit is a conglomerate composed of fragments and pebbles, both angular and rounded, of quartz, chert, igneous rocks, pegmatite, quartzite, limestone, siltstone, clay balls, and dinosaur bones, in a matrix of sand, silt and clay. A lenticular sandstone and conglomerate unit is mapped, together with the underlying conglomerate, as the Westwater Canyon Member. It is interbedded with the Brushy Basin Member, locally merges with the underlying conglomerate, is locally separated from it by green or mottled green and red shale, or is absent. The Westwater ranges from 0 to more than 90 feet thick. It is the host for the major uranium deposits in the Grants-Gallup area, west of the Laguna area.

The Brushy Basin Member is a green and grayish-green mudstone and shale with lenses of sandstone and limestone. The Jackpile Sandstone overlies and laterally intertongues with the Brushy Basin. It is a sandstone similar to the Westwater and is the host rock for most of the uranium deposits in the Laguna area.

Cretaceous rocks

General.--The Cretaceous rocks in the region comprise a complexly intertongued sequence of marine and continental sediments. Figure 4 diagramatically represents the intertonguing of the continental Dakota Sandstone and Mesaverde Group with the marine Mancos Shale.

Dakota Sandstone.--In the area of the Laguna Reservation the Dakota Sandstone is predominantly marginal marine rocks; it becomes progressively more continental toward the south and west. The Dakota is composed of conglomerate and sandstone at the base overlain by siltstone with thin shale layers and sandstone lenses, and of sandstone and siltstone tongues interlayered with the Mancos Shale.

Mancos Shale.--The Mancos Shale is a dark gray clay and silt shale which weathers to broad flat areas, smooth slopes, and badlands topography. Locally, it grades into gray-brown siltstone which in turn grades into the intertonguing sandstone.

Mesaverde Group.--The Mesaverde Group in this region is divided into three formations, the Point Lookout Sandstone, the Crevasse Canyon Formation, and the Gallup Sandstone. The group is composed mostly of continental sandstone and siltstone with minor marginal marine siltstone and shale. The only units of commercial interest in the Laguna area are the Dilco Coal Member and the Gibson Coal Member of the Crevasse Canyon Formation. They contain a few thin beds of coal in a sequence of thin bedded sandstone, siltstone and shale.

Both units are very poorly exposed and the thickness and extent of the coal beds are not well known.

Tertiary Rocks

Santa Fe Formation.--The Santa Fe Formation is an accumulation of Late Tertiary basin deposits occupying the Rio Grande depression and adjacent areas (Wright, 1946). The deposits are mostly unconsolidated, slightly cemented, and are variously deformed and faulted. Beds and layers within the formation range from coarse gravel and fanglomerate to silt and clay, and abrupt changes in type of beds are characteristic (Bryan, 1938). Volcanic rocks, mostly basaltic, are interbedded with the upper part of the Santa Fe.

Gravel Beds.--The gravel beds shown on the geologic map, and many more too small to be shown, are apparently of Late Tertiary and Early Quaternary age. The cemented beds at higher elevations are probably correlative with the Santa Fe Formation; the ones at lower elevations in the valleys are probably related to early stages in the erosional development of the present topography.

Landslides.--Landslides are a conspicuous feature of the Laguna reservation. The largest are shown on the geologic map (fig. 3), uncounted others occur on almost every hill and mesa in the region where Chinle shale, Morrison Formation, or Mancos Shale are capped by sandstone beds or basalt flows. Landslides are more common and larger on the north and west facing slopes, and generally are smaller on the south facing slopes. The landslides were formed during an early wet period, probably late Pleistocene, followed by gradual changes in climate to the present arid conditions. During the wet period large amounts of water percolated through porous sandstones and basalt, soaked and weakened the underlying shales, and produced numerous landslides. As the precipitation lessened, landslides occurred less frequently and less alluvial material was carried away. Eventually the slides stabilized and the valleys were

choked with alluvium which covered many of the lower slides and filled the valleys to form broad flat floors. Flash flooding characteristic of the present arid conditions has produced deep gullies (arroyos) in the alluvium exhuming some landslide blocks.

Alluvium.--Alluvium, colluvium, and recent wind blown sand cover large areas in the region, and are as much as 100 feet thick in some areas. Only the largest and thickest deposits are shown on the geologic map.

Spring Deposits.--Many travertine and gypsiferous calcite spring deposits occur along the southeastern side of the reservation; some are still being formed by saline springs.

Igneous rocks

Mafic intrusives.--Diabase dikes and sills are common in much of the area, and are generally only a few inches to 1 or 2 feet thick but locally are thicker than 10 feet. One sill east of the Sandy mine is 80 feet thick and a laccolith southwest of Mesita is 150 feet thick (Moench and Schlee, 1967).

Volcanic necks and cones occur at several localities. The cones -- sources of many of the lava flows -- are generally a few tens of feet high but they have been considerably eroded so that only massive basalt and coarse fragmental material are left. The volcanic necks vary in size and structure, but are generally composed of breccia and agglomerate cut by dikes and pipes of basalt. The agglomerate and scoria from the neck and dike west of Encinal have been extensively excavated for use as ballast and road metal.

Lava flows.--Late Tertiary or Early Quaternary basaltic or andesitic lava flows cap many of the higher mesas in the region. Those in the northwestern part of the reservation are part of the Mount Taylor Volcano. Younger flows cap many small mesas, especially in the Arroyo

Colorado, and recent basalt flows occur in the valley bottom at Laguna and Mesita.

Structure

The stratified rocks in the western part of the Laguna reservation are relatively undeformed and flat-lying dipping gently northward and westward into the San Juan Basin. Toward the east they are deformed by broad gentle folds, then sharply folded and faulted down to the east by the north-trending Ignacio faulted monocline east of Mesa Gigante. The rocks in the northeast and southeast parts of the reservation are deformed and faulted, generally down to the east, within the Puerco fault zone, which forms the western boundary of the Rio Grande Trench.

MINERAL RESOURCES

General

Known minerals of the Laguna Reservation and environs include the energy resources uranium and coal, and such nonmetallic resources as dimension stone, decorative stone, gypsum, lapidary material, petrified wood, sand and gravel, clay, and tuff. Metallic resources are limited to vanadium, molybdenum and selenium, all of which occur with the uranium. None of the three metals are now being recovered. Current production from deposits on the reservation includes uranium, dimension stone, decorative stone, and to a limited extent, clay, tuff, gem stones, and petrified wood. In the past, limited quantities of gypsum and sand and gravel have been produced. Minor quantities of coal may have been mined for household use, but no record of coal production from these Indian lands is known.

Energy Resources

General

Energy resources on the reservation consist of uranium and coal. Petroleum and natural gas are not known to occur on Laguna lands. Large quantities of uranium are produced by the Anaconda Company. The Continental Oil Co. (Conoco) soon may begin production. Information is sparse and inconclusive about the value of coal occurrences on the reservation.

Uranium

General.--Since the 1920's uranium has been known to occur in New Mexico, but the large deposits in the northwestern part of the State were not discovered until the early 1950's. The large Jackpile-Paquate mine on Laguna lands was discovered by the Anaconda Company in November 1951 in the Jackpile Sandstone.

Known uranium deposits on the reservation occur in the Jackpile Sandstone and the Westwater Canyon Member of the Morrison Formation. Deposits also are found in the Todilto Limestone and in sandstone pipes in the Morrison Formation. The Dakota Formation is mineralized in other nearby areas, and uranium may be present in it on the reservation. About 35 mine occurrences (fig. 5) are known on or near the reservation (Hilpert, 1969).

A large, low-grade deposit in the Westwater Canyon Member is currently being explored on the Bernabe Montana Grant (fig. 5) by Continental Oil Co. (Conoco). The Jackpile Sandstone and the Brushy Basin Member are also present, but contain uneconomic quantities of uranium.

Other deposits on the reservation which have yielded ore in the past are the Woodrow deposit in a sandstone pipe, and the Crackpot and Sandy deposits in the Todilto Limestone and Entrada Sandstone (Moench and Schlee, 1967). Several other deposits are just north of the reservation (fig. 5). The major uranium production (table 3) has come

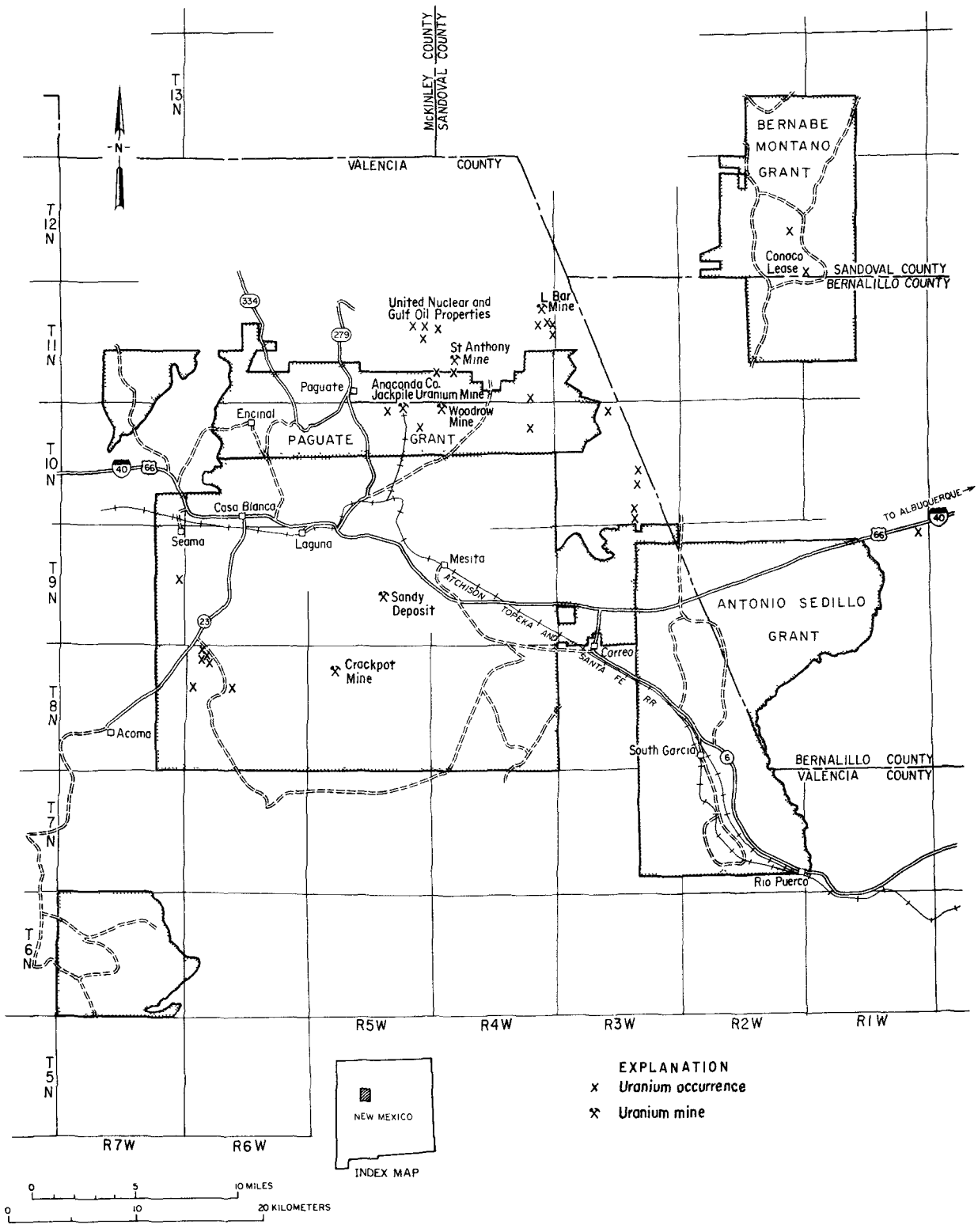

Figure 5.--Map showing uranium mines and occurrences on and near the Laguna Indian Reservation.

from Anaconda's Jackpile-Paguate mine. Small tonnages have been reported from the Crackpot, Woodrow, and Sandy deposits.

Table 3.--Uranium production on Laguna Reservation.

Mine[1/]	Location: Section	Location: Township	Location: Range	Crude ore production: (tons)	Crude ore production: (metric tons)
Jackpile-Paguate...		10 N 11 N	5 W 5 W	11,444,747	10,382,674
Woodrow.....	SE¼ 36	11 N	5 W	5,327	4,833
	N½NW¼ 1	10 N	5 W		
Crackpot.....	NW¼NW¼ 8	8 N	5 W	8,395	7,615
Sandy.....	SE¼ 22	9 N	5 W	939	851
Wind Whip.....	SW¼NW¼ 35	11 N	5 W	2/	-----

1/ Other small deposits may have produced very small tonnage, but no records are available.

2/ Unknown. Probably part of Jackpile-Paguate now.

Source: U. S. Bureau of Mines.

Jackpile-Paguate Mine.--The Jackpile-Paguate mine is the largest, and only current producing, mine on the reservation. The mine originally was two separate, open-pit operations which now have been enlarged into a single pit. Recently, underground operations were started at two places in a southern extension of the ore body. To date, however, virtually all production has been from open-pits.

Current production from the mine is 1,500 to 1,800 tons (1,361 to 1,633 mt) per day from the open-pit operation and 500 to 600 tons (454 to 544 mt) per day from the underground operations. About 2,000 acres (810 ha) of land have been disturbed. Part of the mine is being backfilled and some experimental revegetation has been tried. An Anaconda representative indicated that the mine has, at this time, about 8 to 10 years of reserves, but exploration is continuing and large reserves may be developed. In addition to known reserves, several

million tons of low-grade ore have been stockpiled. If uranium prices continue to increase, it is probable that the uranium in the stockpile will be recovered.

The ore produced from the Jackpile deposit ranges between 0.01 percent and about 5 percent U_3O_8, and averages about 0.3 percent. Vanadium content averages 0.2 to 0.3 percent, but, owing to milling difficulties, the vanadium is not recovered. The ore also contains 0.03 to 0.04 percent molybdenum and a trace of selenium. Neither the molybdenum nor selenium is economically recoverable now.

Total crude ore production from the mine, since operations began in 1952, approximates 11.5 million tons.

A new lease agreement between the Indians and Anaconda was negotiated and signed on June 10, 1974. The Secretary of the Interior approved it in January 1975. Main elements of the lease are a new royalty schedule and a new definition of crude ore value. The schedule provides that the royalty be a percentage of the crude ore value, based on a sliding scale (that is, the percentage royalty increases as the value of the crude ore increases).

Woodrow Mine.--The Woodrow mine, located on the section line between sec. 36, T. 11 N., R. 5 W., and sec. 1, T. 10 N., R. 5 W., is in a sandstone pipe in the Brushy Basin Member. Schlee (1963) hypothesized that the sandstone pipes in the area are the results of spring activity that may have been aided by structural deformation of the region. Only the Woodrow pipe is mineralized. The deposit, mined between 1954 and 1956, yielded 5,327 tons (4,833 mt) of ore, which averaged 1.26 percent U_3O_8, about 10 times as great as the nearby Jackpile mine. The deposit was developed by a vertical shaft about 230 feet deep (70 m).

Crackpot Mine.--The Crackpot mine, S½SW¼NW¼ sec. 8, T. 8 N., R. 5 W., is in the Todilto Limestone. The deposit was mined by open pit methods and was depleted by 1955. Total production was about 8,395 tons (7,616 mt) averaging 0.13 percent U_3O_8 (Moench and Schlee, 1967). Only a few acres were disturbed, and no rehabilitation was required.

Sandy Mine.--The Sandy mine, is in secs. 22 and 27, T. 9 N., R. 5 W. Uranium minerals are in both the Entrada Sandstone and the overlying Todilto Limestone. The deposits have produced 939 tons (852 mt) averaging 0.12 percent U_3O_8. Mining was from several small open-pits. The ore was in a series of deposits over an area about 3,000 feet (915 m) long by about 1,200 feet (366 m) wide.

Conoco Lease.--The Continental Oil Co. (Conoco) has discovered a large low-grade uranium deposit in the southern part of the Bernabe Montana Grant in Bernalillo and Sandoval Counties. The company has four leases in Tps. 11 and 12 N., Rs. 1 and 2 W., totaling about 6,750 acres (2,733 ha), and was intensively exploring part of the lease holdings in September 1975. Drilling was on a 400-foot (122 m) grid and extended to about 1,800 feet (549 m) below the surface. The company indicates that mineralization is in the Westwater Canyon Member. They stated further that although the Jackpile sandstone is present on the property it is not mineralized. A decision has not yet been made whether or not to develop a mine.

Outlook.--In summary, the present situation with regard to uranium development on the reservation is (1) Anaconda will continue to operate the Jackpile-Paguate mine for at least 8 to 10 years, (2) the Crackpot and Woodrow mines are depleted, (3) the Sandy deposit may have potential for development if U_3O_8 prices continue to rise, and (4) the Conoco discovery on the Bernabe Montana Grant may become a producing property in the relatively near future. In all probability, barring a drop in the price of uranium, the Jackpile-Paguate property will continue yielding ore beyond the 8 to 10 years suggested by Anaconda representatives.

The productive life of the Jackpile-Paguate property depends on several factors, chief among them being (1) the continued increase in the price of uranium (2) success in developing new and larger reserves, and (3) success in the new underground operations.

The Sandy deposit may have some possibilities for development.

The Anaconda Company extensively explored the property in the early 1950's, and the U. S. Geological Survey studied the property and published a description of it (Moench and Schlee, 1967). At the time of the two investigations the property was uneconomic. However, because of the increased price of U_3O_8 (recently about $20.00 per pound) and projections of increasing demands and further price increases, it may be possible to develop the property by in-situ or heap-leaching methods. An in-situ mining operation recently has been started in Texas (White, 1975), enhancing the economic possibilities of that method. The in-situ mine in Texas is leaching rock containing as little as 0.05 percent U_3O_8, and Western Nuclear's heap-leaching operation in Wyoming is recovering U_3O_8 from ore of about the same grade. The Sandy property with a uranium content of 0.08 to 0.22 percent U_3O_8 may be amenable to either one or both of these methods, if sufficient reserves can be developed.

Coal

Information concerning coal is meager, but any strippable reserves are modest at best. Coal resources on the reservation are so poorly documented that it is impossible to determine their quantity and quality. Available records indicate that all known coal resources are located west of Paguate, in the Antonio Sedillo Grant, and in the Bernalillo County portion of the Bernabe Montana Grant (fig. 6).

All coal in the east Mount Taylor field is in the Crevasse Canyon Formation of the Cretaceous Mesaverde Group. The Crevasse Canyon Formation commonly contains two coal-bearing units, the Dilco, or lower coal member, and the Gibson, or upper coal member. According to Kottlowski (1971), Dilco coal occurs only in parts of two sections on the reservation; other coal occurrences are in the Gibson coal member. Limited sampling indicates it is high volatile bituminous with less than 1 percent sulfur.

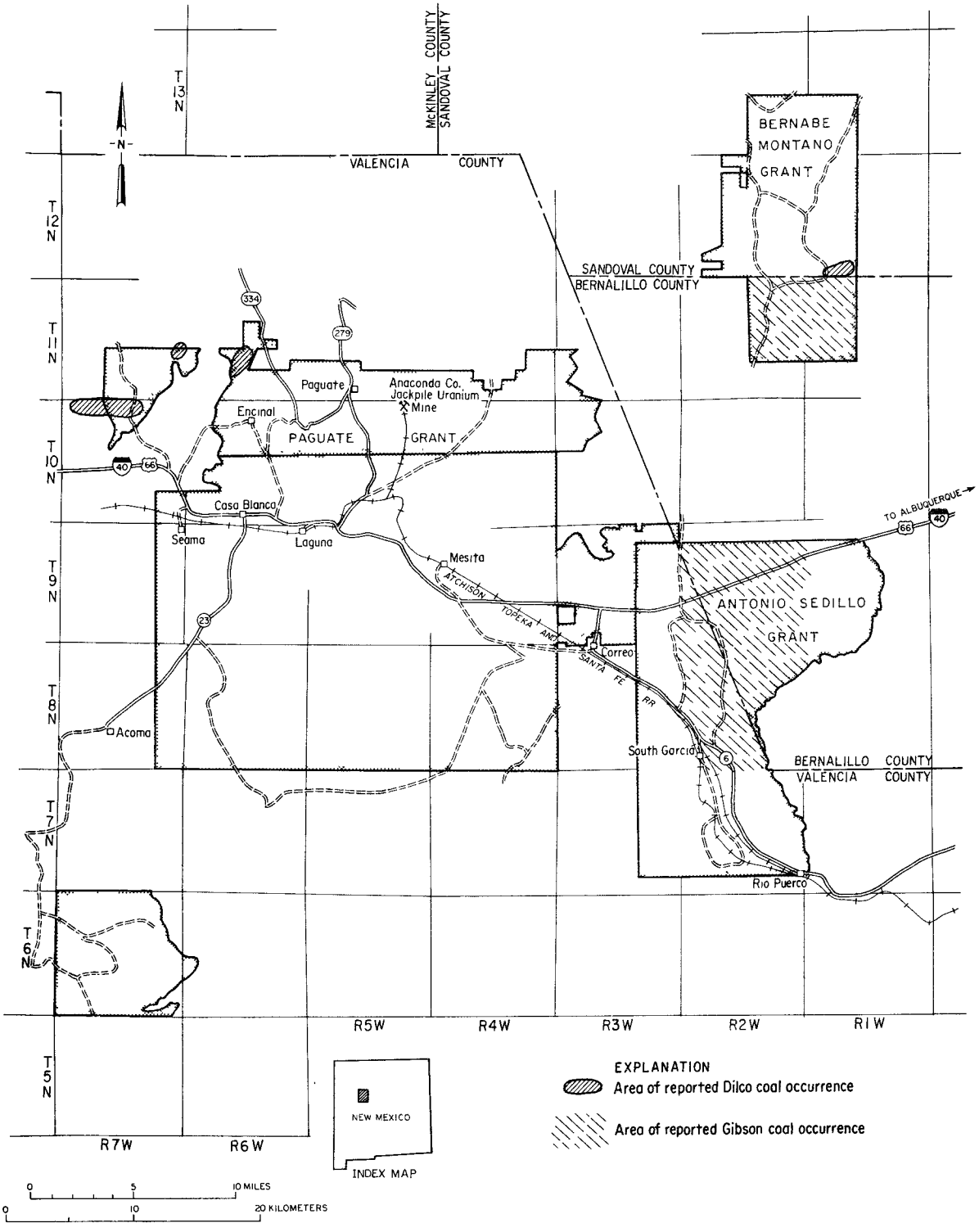

Figure 6.--Map showing coal occurrences on the Laguna Indian Reservation.

West of Paguate.--Coal was reported by Hunt (1936) in sec. 24, T. 11 N., R. 7 W., secs. 3-6, T. 10 N., R. 7 W., and in T. 11 N., R. 6 W. Hunt classified it as the Dilco coal member and noted that the Gibson coal member is probably present. Coal, at the outcrop, is reported to be only 14 inches (35.6 cm) thick, but the thickness of overburden is not given.

Antonio Sedillo Grant.--Coal in the Gibson coal member occurs on the Antonio Sedillo Grant in Tps 8 and 9 N., R. 2 W. The thickness is not reported, but both Hunt (1936) and Kottlowski (1971) report coal under thin overburden in the area.

Bernabe Montana Grant.-- Coal in the Bernabe Montana Grant occurs in Tps 11 and 12 N, Rs 1 and 2 W. Hunt (1936) states:

> "Most of the portion of this grant lying in Sandoval County includes only non-coal-bearing formations. The Dilco coal member is present just north of the Sandoval-Bernalillo County line, but it is thin and contains no coal beds exceeding 14 inches in thickness. There is a small area of the Gibson coal member east of the Rio Puerco. In the portion of the grant lying in Bernalillo County there are many outcrops of the Gibson coal member containing beds of coal. The coal-bearing and other Cretaceous rocks of the grant are broken by numerous faults. Minor faults, which are not recorded on the map, may make mining operations difficult."

There has been no recorded production of coal from within the reservation, although minor quantities may have been mined for private use. The coal tends to be thin (less than 30 inches (76 cm)) and lenticular. No single bed has been traced over large areas.

Outlook.--The available data concerning coal on the reservation are so limited that a realistic appraisal of the development potential cannot be made.

U. S. Bureau of Mines investigations into strippable and underground coal reserves nationally, by the Staff (1971) and Matson and White (1975), list no coal reserves for areas within the reservation. However, coal resources on the Sedillo and Montano Grants have not been adequately investigated. In most areas, coal outcrops are

covered or do not exist, and no drill-hole information is available. Therefore, far more information than is presently available will be required in order to make any valid assessment.

Oil and gas

According to the Conservation Division of the U. S. Geological Survey, the nearest petroleum production to the reservation is the Elmer L. White well No. 3 in sec. 13, T. 15 N., R. 10 W. The well, completed in April 1956, initially yielded 12 barrels of oil per day, but is now abandoned.

The sedimentary section is thin--less than 5,000 feet (1,525 m) thick and the possibility of oil and gas discovery is not promising. The U. S. Geological Survey's Conservation Division rates the chance of discovery for oil and gas to be 10 percent or less.

Nonmetallic Mineral Resources

General

Nonmetallic mineral resources of the reservation are limited to dimension and decorative stone, gypsum, selenite (desert) roses, lapidary material, tuff, petrified wood, sand and gravel, and clays. The Indians currently are producing and marketing dimension and decorative stone, selenite roses, gem stones, and tuff. This operation of the Indians is called Laguna Rock Enterprises and is at Laguna. Clays are mined in small quantities for pottery-making. Tuff is sold for use as a molding stone. Sand and gravel are not presently produced on the reservation.

Dimension and decorative stone produced on the reservation includes sandstone and limestone. Travertine occurs in large quantities in the eastern part of the Indian land.

Sandstone

The Indians mine, shape, and market both a bedded red sandstone for use as a building stone, and flagstone and a white sandstone for dimension stone. Both materials are also sold in rough form for use in landscaping.

The stone is mined from several small quarries (fig. 7). Reserves are large.

Limestone

Limestone occurs in various places on the reservation but is only mined as the need arises. Use is almost exclusively for building purposes. Reserves are large.

Travertine

Travertine (calcium carbonate), deposited from spring or ground water, occurs in large quantities in the Antonio Sedillo Grant (fig. 7). The rock, locally called marble, is as yet undeveloped, but Laguna Rock Enterprises displays both slabbed and rough specimens and mines and sells the material on request. The stone is available in several colors and, when polished, is a handsome material used primarily as a decorative or facing stone.

An earlier attempt evidently was made to quarry and market the rock, but it proved unsuccessful. If a market could be developed, there is enough travertine on the reservation to provide employment for some tribal members for many years.

Petrified Wood

Petrified wood occurs on Indian land at various locations. Small

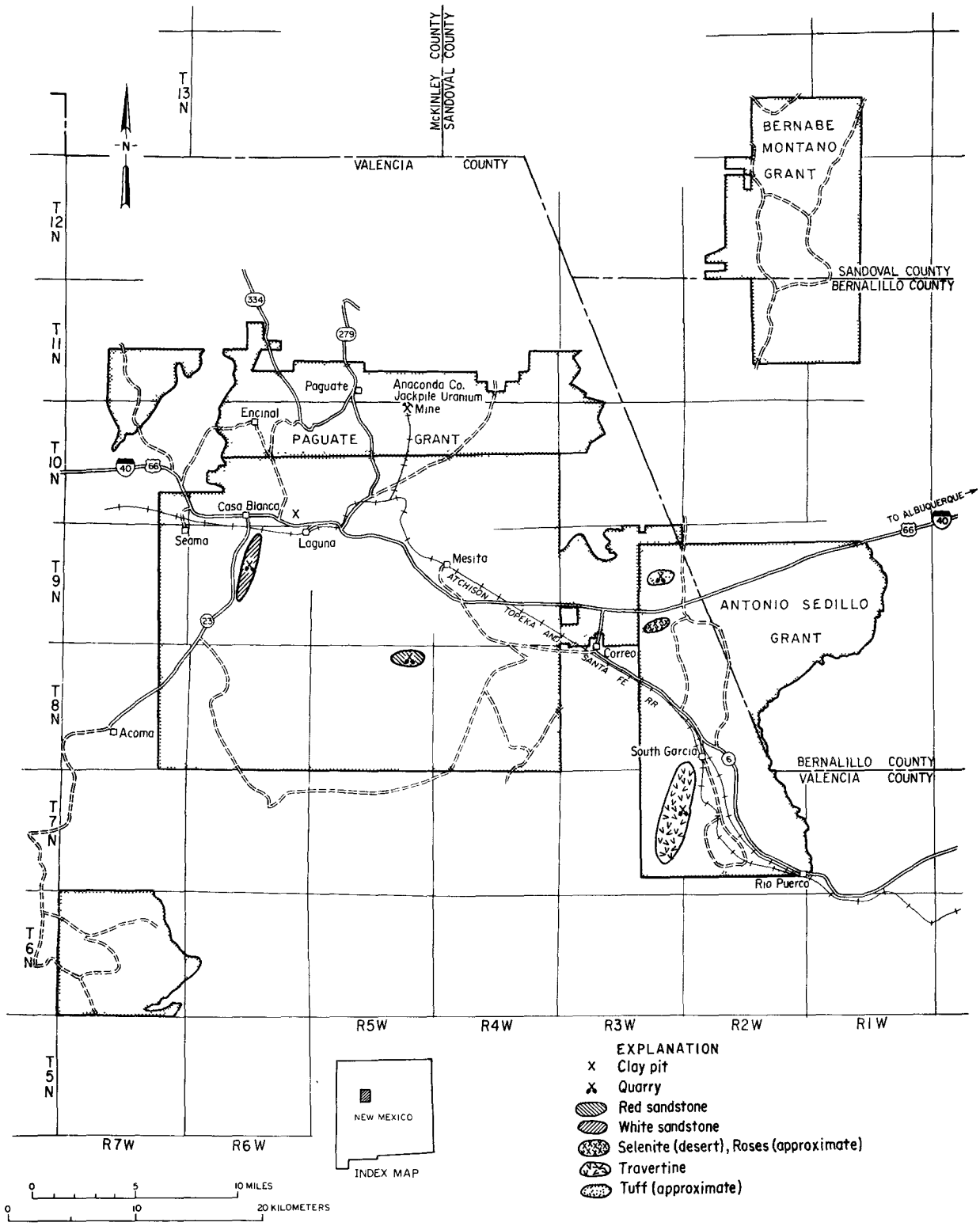

Figure 7.--Map showing rock product occurrences on the Laguna Indian Reservation.

quantities are being recovered and sold mostly for construction of rustic fireplaces. Uses are limited because the material is not well silicified, but the Indians probably will be able to continue to mine and sell it at about the same rate as in the past. Reserves are unknown.

Selenite (Desert Roses)

Another item produced and sold by the Indians at Laguna Rock Enterprises is selenite or desert roses. The roses are formed by deposition from ground water in sand and are found in abundance at one location on the reservation (fig. 7). Masses of crystals up to 3 feet (92 cm) or more across are dug and sold for specimens. A representative of the Laguna Rock Enterprises group indicated that a few are bought for use in fireplaces. Reserves of desert roses probably are sufficient to last for many years.

Lapidary Material

Agate and chalcedony are found scattered over the reservation. Some of the material is collected and sold by the Indians. Reserves likely are large enough to last indefinitely.

Tuff

At least one deposit of tuff (cemented volcanic ash) occurs on the reservation (fig. 7). Rock from the deposit is a porous, soft, friable, material. Tuff has several applications as an abrasive, a molding sand, and in other uses for which a porous material is needed. An interesting use found for this tuff is as a molding stone. Indian jewelry makers first prepare a flat surface on the material, then cut a design in it, and pour silver into the design mold. The casting thus produced is used as a setting for semi-precious stone, such as turquoise, coral, and jet. The end product is the distinctive Indian jewelry of the southwest.

If industrial applications for the material could be proved and if the known deposit or other deposits that may occur on the reservation are large enough, then a substantial mining operation might be developed.

Gypsum

Large reserves of gypsum are found on the reservation (fig. 8). Nearly all the known gypsum resources are in the Todilto Limestone and occur in the eastern part of the reservation from Mesita to the Antonio Sedillo Grant. A small area in T. 8 N., R. 3 W., is known to be underlain by gypsum of the Permian Yeso Formation (Weber and Kottlowski, 1959).

A small quarry located near the Santa Fe Railroad in sec. 12, T. 9 N., R. 5 W., near Mesita (fig. 8) was operated during the 1920's. The material reportedly was used for rock dust in coal mines. The property was under lease in 1946, but it is unknown whether any gypsum was mined. The bed is reported to be 83 feet (25 m) thick with little or no overburden. Analysis of samples showed 95.9 percent gypsum. Commercial gypsum is defined as 70 percent and above.

The bed near Mesita can be traced for about 16 miles (26 km) southeast where it is described as being 90 to 110 feet (27 to 34 m) thick on the Antonio Sedillo Grant near Suwannee. Analysed material contained about 93 percent gypsum. The deposit, occurring over a large area under thin overburden, has been mined intermittently for agricultural gypsum.

The gypsum near Mesita and Mesa Gigante is close to and readily accessible to the railroad and highway, and constitutes a major resource of gypsum, at least 1 billion tons, of which about 200 million tons are immediately available by open pit mining methods.

The gypsum occurring in Permian rocks in T. 8 N., R. 3 W., is reported by Weber and Kottlowski (1959) to be part of sequence of marine sediments 1,300 feet (397 m) thick. The gypsum is 1 to 100 feet (30 cm to 31 m) thick in various beds throughout the sequence. Composition is not reported, but the deposit is in a remote area

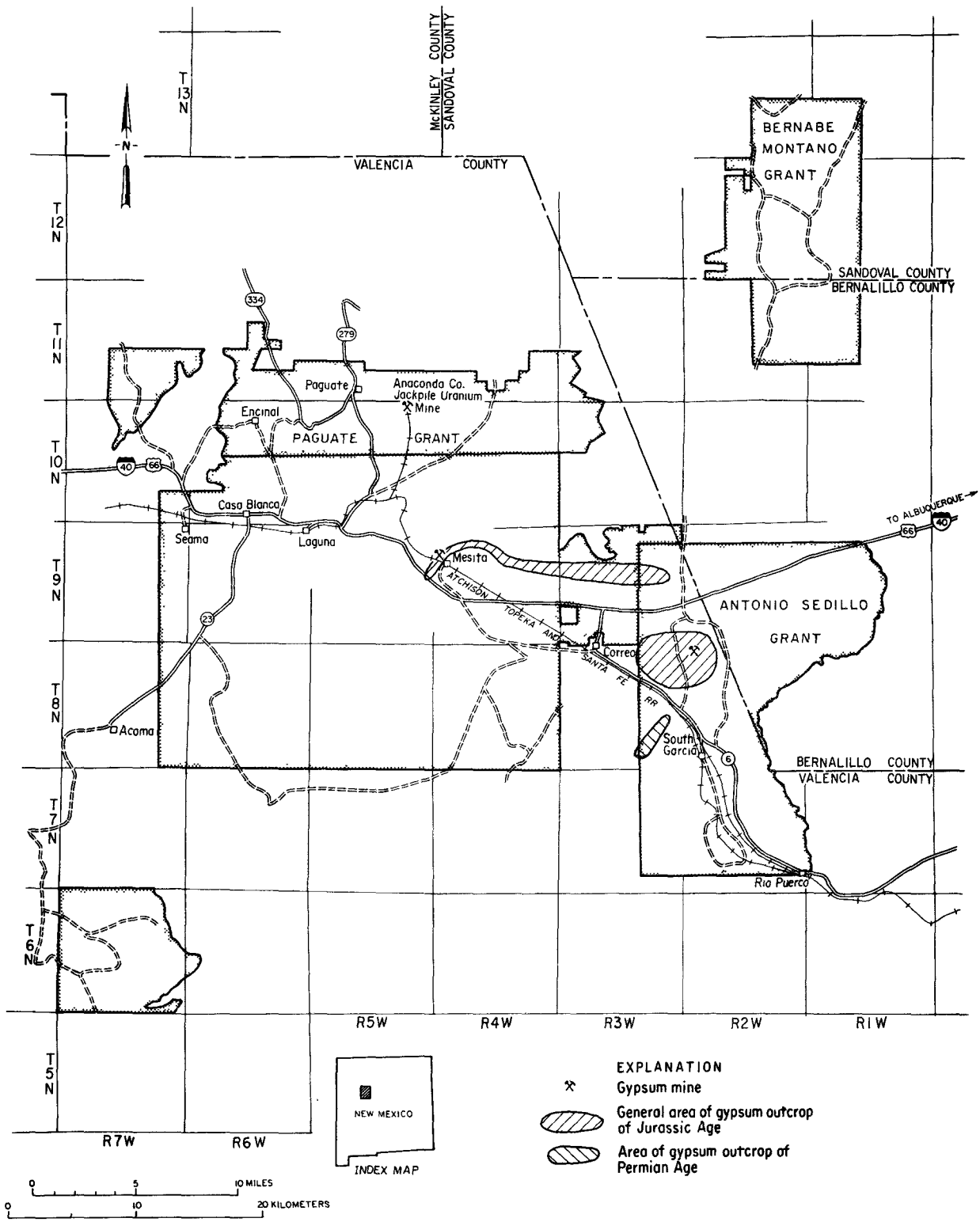

Figure 8.--Map showing gypsum occurrences and inactive gypsum mines on the Laguna Indian Reservation.

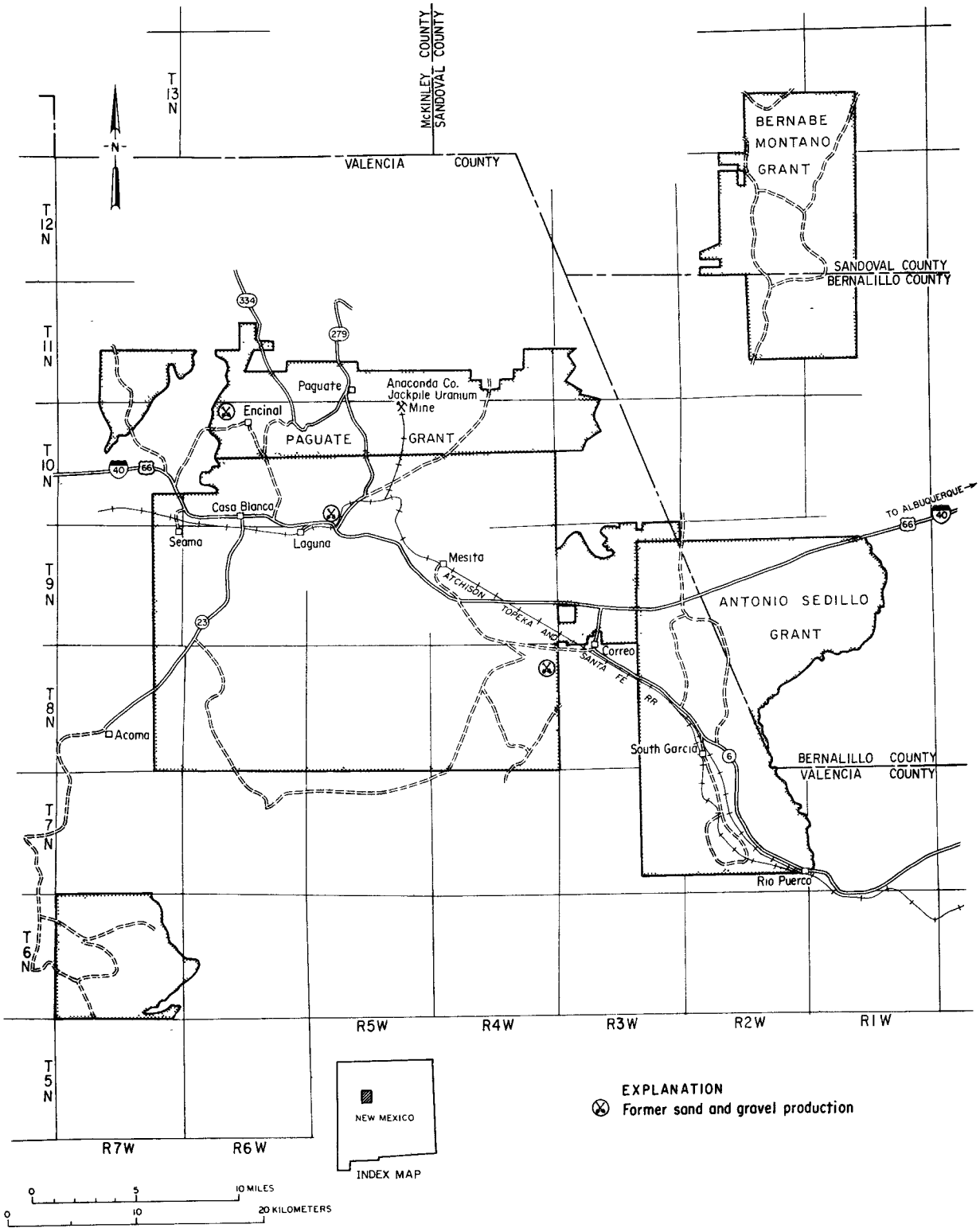

Figure 9.--Map showing location of former sand and gravel productive sites on the Laguna Indian Reservation.

TABLE 4. Locations of sand and gravel production

Producer	Location: Section	Township	Range	Total acres in permit: (acres)	(Hectares)
Unknown....	12	8 N	4 W	1/	
State.....	32	10 N	5 W	31.68	12.83
Do.....	23	10 N	5 W	17.9	7.25
	26	10 N	5 W		
Do 2/	4	10 N	6 W	124.4	50.38
	5	10 N	6 W		

1/ Unknown

2/ Permit extended into sec. 33, T. 11 N., R. 6 W.

MARKETS

With the exception of uranium, all mineral commodities currently produced on the reservation are confined to a local or regional market. If a wallboard or cement plant were to locate on or near the reservation to utilize gypsum, the products of such a plant might also have to compete in the national market.

MINERAL LEASING

Federal regulations require established royalty and rental fees for mineral leases on Indian reservations. Bonds must be posted by the lessee for each lease. Regulations pertaining to mineral leasing are found in the Code of Federal Regulations, 25CFR and 30 CFR. Requirements for bonds are as follows:

For less than 80 acres	$1,000
For 80 acres and less than 120 acres	1,500
For 120 acres and not more than 160 acres	2,000
For each additional 40 acres, or part thereof, above 160 acres	500

The bond for minerals other than oil and gas may be less, provided

the Secretary of the Interior, with consent of the Tribe, agrees; or a lessee may file a bond of $15,000 for all leases in one State if the total acreage does not exceed 10,240. A lessee also may file a bond of $75,000 for nationwide coverage.

Lessees may acquire more than one lease, but a single lease may not exceed 2,560 acres for minerals other than coal. Ordinarily, coal leases also are limited to 2,560 acres, but upon application, leases can be combined. Leases may be made for any specified term not to exceed 10 years. A diagram of the procedure for obtaining leases and mining permits is shown in figure 10.

Rentals for minerals are set at $1.00 per acre per year and a development expenditure of not less than $10.00 per acre per year,

Unless otherwise authorized by the Commissioner of Indian Affairs, the minimum rates for minerals other than oil and gas shall be as follows:

"(a) For substances other than gold, silver, copper, lead, zinc, tungsten, coal, asphaltum and allied substances, oil, and gas, the lessee shall pay quarterly or as otherwise provided in the lease, a royalty of not less than 10 percent of the value, at the nearest shipping point, of all ores, metals, or minerals marketed."

"(b) For gold and silver the lessee shall pay quarterly or as otherwise provided in the lease, a royalty of not less than 10 percent to be computed on the value of bullion as shown by mint returns after deducting forwarding charges to the point of sale; and for copper, lead, zinc, and tungsten, a royalty of not less than 10 percent to be computed on the values of ores and concentrates as shown by reduction returns after deducting freight charges to the point of sale."

"(c) For coal the lessee shall pay quarterly or as otherwise provided in the lease, a royalty of not less than 10 cents per ton of 2,000 pounds of mine run, or coal as taken from the mine, including what is commonly called 'slack'."

In addition to the Federal regulations, the tribe requires that some Indians be hired by any firm extracting minerals from reservation lands.

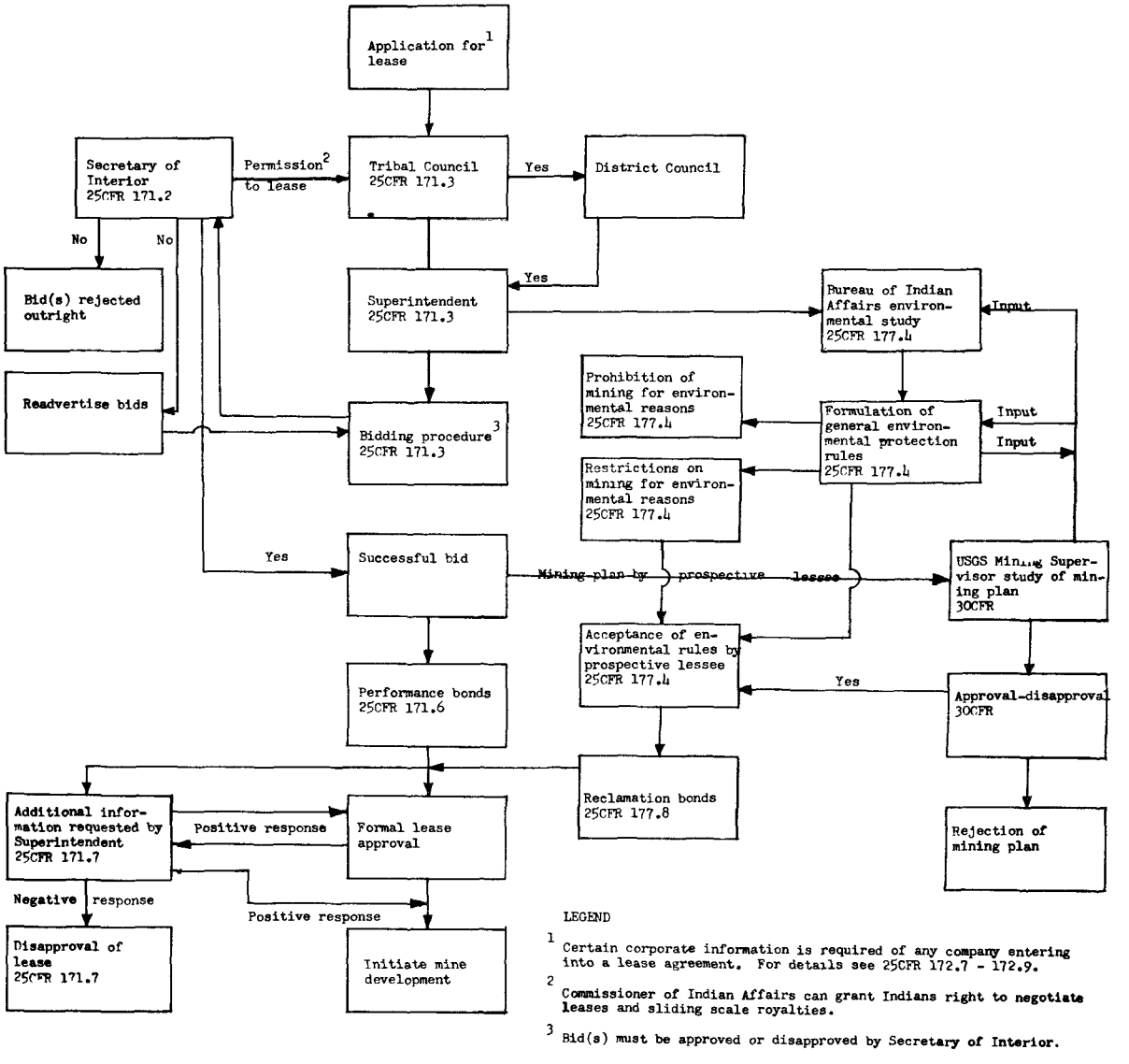

Figure 10.--Schematic diagram outlining procedure for obtaining lease on the Laguna Indian Reservation.

RECOMMENDATIONS FOR FUTURE WORK

Recommendations for future work on the Laguna reservation are as follows:

1. A field examination of the Sandy uranium deposits to determine whether enough mineralized rock is present at a grade of 0.05 percent U_3O_8 to sustain a mining operation that would recover yellow cake by either heap-leaching and/or in-situ leaching methods.

2. A field examination, including a drilling program, to determine whether low-grade mineralization found by Continental Oil Co. on land north of their present leases would be amendable to in-situ leaching.

3. A field examination to determine location, quality, and quantity of, coal on the reservation. Because coal outcrops are often covered the field examination and assessment must include drilling.

4. Local and national market potential for several nonmetallic reources on the reservation should be more fully investigated.

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